MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2018/2019

EPM2036 – CONTROL THEORY

(RE / TE)

2 MARCH 2019
2:30 p.m - 4:30 p.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 8 pages including cover page with 4 Questions only. Laplace Transform Table is included in Appendix.
2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please write all your answers in the Answer Booklet provided.

Question 1

a) A system is described by the following differential equation.

$$y''(t) + 7y'(t) + 12y(t) = x'(t) + 2x(t)$$

$x(t)$ and $y(t)$ are the input and output respectively. Assuming zero initial conditions,

i. Find the transfer function $Y(s)/X(s)$.

[3 marks]

ii. Identify the finite pole(s) and zero(s) for the transfer function.

[2 marks]

iii. Determine the output response $y(t)$, given that the input $x(t)$ is a unit step input.

[5 marks]

iv. Prove the final value theorem with the output.

[2 marks]

b) Using Mason's rule, find the transfer function $C(s)/R(s)$ for the signal flow graph in Figure 1.

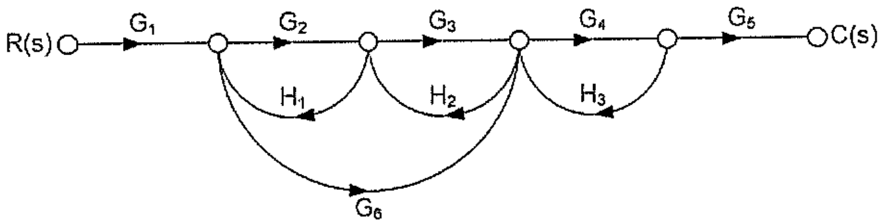

Figure 1

[13 marks]

Continued ....

Question 2

a) The open loop transfer function of a second order system is given as

$$G(s) = \frac{16}{s(s+4)}$$

i. Prove that the step response of the system is underdamped. **[4 marks]**

ii. Determine the oscillation frequency, ω **[3 marks]**

iii. Determine the time t_{max} at which the maximum overshoot occurs. **[3 marks]**

iv. Determine the overshoot. **[3 marks]**

b) Given the characteristics equation as follows

$$s^4 + Ks^3 + 2s^2 + s + 1 = 0$$

Using Routh criterion, determine the range of K for stability. **[12 marks]**

Continued ....

Question 3

The following is an open loop transfer function of a unity feedback system.

$$KG(s) = \frac{K(s+2)}{s(s+3)(s+4)}$$

a) Determine all poles and zeros.

[3 marks]

b) Sketch the root loci of the system.

[12 marks]

c) If $K = 1$, draw the asymptotic magnitude bode plot for the function $G(s)$ on the semi log graph.

[10 marks]

Continued ....

Question 4

A unity feedback system shown in Figure 2 has a plant transfer function $G(s)$. PI controller $K(s)$ is designed to control the plant.

$$G(s) = \frac{1}{(s+3)(s+4)}$$

$$K(s) = k_P + \frac{k_I}{s}$$

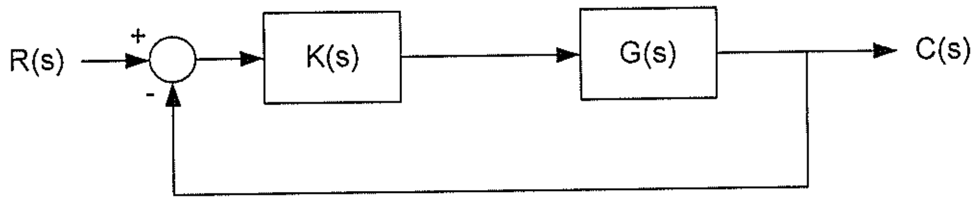

Figure 2

a) If the steady-state error for a unit ramp input must be no more than 0.06, determine k_I.

[9 marks]

b) Find the range of k_P for the system to be stable.

[9 marks]

c) Using the critical values for k_I and k_P, determine the closed-loop transfer function.

[7 marks]

Continued ....

Appendix

Laplace Transform Pairs

$f(t)$	$F(s)$
Unit impulse $\delta(t)$	1
Unit step $u(t)$	$\frac{1}{s}$
t	$\frac{1}{s^2}$
$\frac{t^{n-1}}{(n-1)!}$ (n = 1, 2, 3, …)	$\frac{1}{s^n}$
t^n (n = 1, 2, 3, …)	$\frac{n!}{s^{n+1}}$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$\frac{t^{n-1}}{(n-1)!}e^{-at}$ $(n = 1,2,3, \ldots)$	$\frac{1}{(s+a)^n}$
$t^n e^{-at}$ $(n = 1,2,3, \ldots)$	$\frac{n!}{(s+a)^{n+1}}$
$sin\,\omega t$	$\frac{\omega}{s^2+\omega^2}$
$cos\,\omega t$	$\frac{s}{s^2+\omega^2}$
$sinh\,\omega t$	$\frac{\omega}{s^2-\omega^2}$
$cosh\,\omega t$	$\frac{s}{s^2-\omega^2}$

Continued …….

$f(t)$	$F(s)$
$\frac{1}{a}(1-e^{-at})$	$\frac{1}{s(s+a)}$
$\frac{1}{b-a}(e^{-at}-e^{-bt})$	$\frac{1}{(s+a)(s+b)}$
$\frac{1}{b-a}(be^{-bt}-ae^{-at})$	$\frac{s}{(s+a)(s+b)}$
$\frac{1}{ab}\left[1+\frac{1}{a-b}(be^{-at}-ae^{-bt})\right]$	$\frac{1}{s(s+a)(s+b)}$
$\frac{1}{a^2}(1-e^{-at}-ate^{-at})$	$\frac{1}{s(s+a)^2}$
$\frac{1}{a^2}(at-1+e^{-at})$	$\frac{1}{s^2(s+a)}$
$e^{-at}\sin\omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at}\cos\omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$
$\frac{\omega_n}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin\omega_n\sqrt{1-\zeta^2}t$	$\frac{\omega_n{}^2}{s^2+2\zeta\omega_n s+\omega_n{}^2}$
$-\frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin\left(\omega_n\sqrt{1-\zeta^2}t-\phi\right)$ $\phi=\tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{s}{s^2+2\zeta\omega_n s+\omega_n{}^2}$

Continued ....

$1-\frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin\left(\omega_n\sqrt{1-\zeta^2}t+\phi\right)$ $\phi=\tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{{\omega_n}^2}{s(s^2+2\zeta\omega_n s+{\omega_n}^2)}$
$1-\cos\omega t$	$\frac{\omega^2}{s(s^2+\omega^2)}$
$\omega t-\sin\omega t$	$\frac{\omega^3}{s^2(s^2+\omega^2)}$
$\sin\omega t-\omega t\cos\omega t$	$\frac{2\omega^3}{(s^2+\omega^2)^2}$
$\frac{1}{2\omega}t\sin\omega t$	$\frac{s}{(s^2+\omega^2)^2}$
$t\cos\omega t$	$\frac{s^2-\omega^2}{(s^2+\omega^2)^2}$
$\frac{1}{\omega_2^2-\omega_1^2}(\cos\omega_1 t-\cos\omega_2 t)\ (\omega_1^2\neq\omega_2^2)$	$\frac{s}{(s^2+\omega_1^2)(s^2+\omega_2^2)}$
$\frac{1}{2\omega}(\sin\omega t+\omega t\cos\omega t)$	$\frac{s^2}{(s^2+\omega^2)^2}$

End of Page